Center Innovation Fund: LaRC CIF

Holistic High-Fidelity Modeling Strategy for Advanced Composites

Completed Technology Project (2013 - 2014)

Project Introduction

Engineering demands of current and next generation aerospace vehicles dictate the use of state-of-the-art materials. Advanced Fiber-Reinforced Polymer Composites (FRP) exhibit many features that render them suitable for such application, including high specific strength/stiffness, damage resistance and tolerance, and multi-functionality. However, the level of accuracy of available modeling tools, and/or their limited applicability, inhibits the realization of high-fidelity virtual testing, essential to realize concepts such as the Digital Twin - a vital tool for real-time prognosis of high-performance structures. This proposal aims to: (i) develop and validate a holistic modeling strategy capable of high-fidelity simulation of damage in composite materials that can ultimately enable the Digital Twin, (ii) perform experiments of increasing complexity that can validate and help develop the proposed modeling strategies, and (iii) gather detailed information of constituent-level processes, key to the damage mechanisms exhibited by FRP. This will serve to assess the fidelity of the modeling strategies, while improving current understanding of in-service damage mechanisms.

Numerous physical and empirical models have been proposed to simulate damage in FRP. Although some of these models have been successful in capturing isolated failure modes, their assumptions can be very limiting: often they require an “a priori” knowledge of the type of failure, and/or are only applicable to a type of loading and/or expected failure mechanisms. Additionally, there is a lack of experimental data that can be used to validate approaches aimed at the high-fidelity modeling of damage in FRP.

Our goal was to improve the safety and efficiency of advanced composite structures while enabling novel designs. To this end we developed a precursor Digital Twin concept. The basis of the Digital Twin was an experiment developed by Langley engineers for investigating the phenomenon of delamination migration in fiber-reinforced polymeric composite laminates. A counterpart finite element model of the experiment was created and a LabView program was written to act as a data conduit between the experiment and the finite element model. Although in its very preliminary stage, the precursor Digital Twin was completed. The basic concept is that during the experiment an existing delamination crack will grow and eventually turn towards a neighboring ply interface under cyclic loading conditions. At the same time, the finite element model of the experiment (the Digital Twin object) is conducted to predict the number of cycles required for the delamination to reach a certain stage within the test specimen. The finite element model, in theory, can be used to reduce the cyclic loading via the conduit if the current loading level is predicted to exceed some pre-determined lifetime of the actual test specimen. The setup is thus meant to act as a precursor Digital Twin, by demonstrating the feasibility of a real-time computational model being able to dictate and control the outcome of a physical activity (in this case the delamination test).

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Langley Research Center (LaRC)

Responsible Program:

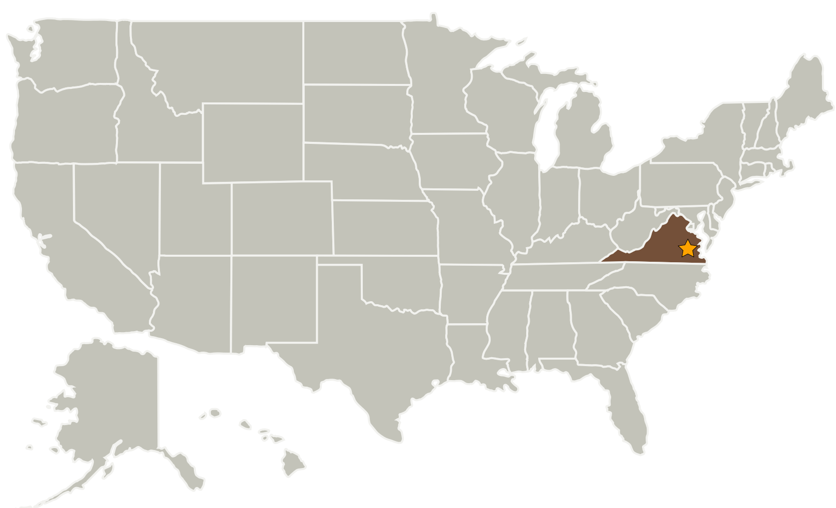
Center Innovation Fund: LaRC CIF

Anticipated Benefits

This work is crucial in applying the Digital Twin concept to structures made of advanced FRP (IRAD-topic #2). Additionally, the tools developed can eventiually be used in the virtual design and certification of these high-performance structures, improving reliability and decreasing associated costs (IRAD-topic #7).

The experiments will provide test cases of growing complexity that can be used to assess the Digital Twin concept. Additionally, key physical understanding of the damage processes in advanced FRP can also be obtained.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Langley Research Center(LaRC)	Lead Organization	NASA Center	Hampton, Virginia

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Julie A Williams-byrd

Project Manager:

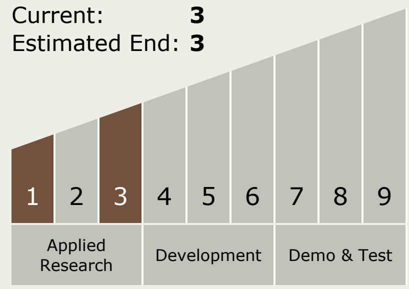
Michael W Czabaj

Principal Investigator:

James G Ratcliffe

Technology Maturity (TRL)

Start: **1**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.2 Structures
    └ TX12.2.4 Tests, Tools and Methods

Primary U.S. Work Locations

Virginia